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PROJECT MERCURY

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Introduction

Project Mercury is the United States' initial step in a program of manned exploration of space. The specific scientific objective of Project Mercury is to investigate man's capabilities in those environments associated with manned space flight. The corollary technological objectives are to develop the techniques and equipment for manned space flight and to demonstrate these by successfully accomplishing manned orbital flight and return. A program such as Mercury has many facets—earlier papers in this conference by Mr. H. A. Soule and Dr. R. B. Voas have covered the tracking and ground instrumentation system and the human system, or astronaut selection, training, and performance evaluation. The purpose of the present paper is to discuss the project history and management briefly and to dwell at greater length on the problems of hardware research and development.

HISTORY AND MANAGEMENT

History

Project Mercury had its beginnings during the middle of late 1950's in the basic research programs of the National Advisory Committee for Aeronautics. Serious effort on the project was underway in NACA during 1958 and in the late summer of 1958 it has progressed far enough to discuss before various Congressional Committees while the National Space Act of 1958 was under detailed consideration. The Space Act was passed and it became clear that NACA was to become the nucleus of the new National Aeronautics and Space Administration and was to have responsibility for the manned space flight program. At this time a joint panel was set up with the Advanced Research Projects Agency of the Department of Defense and a detailed plan for Project Mercury was developed from the work that NACA and various DOD groups had been doing during the past year or two. Within a week after the NASA officially came into being in October 1958, the Administrator of NASA approved Project Mercury and authorized the establishment of the Space Task Group at Langley Field to implement the project. The Space Task Group began with a group of 35 employees drawn from the Langley Research Center and about 10 employees of the Lewis Research Center. During the intervening 2½ years the group has grown to about 800 in number.

Management

The accomplishment of Project Mercury has required the development

of a management organization to utilize effectively the broad spectrum of Government agencies and industry which such a complex program requires. This organization is shown in Fig. 1.

Over-all direction of Project Mercury is the responsibility of the National Aeronautics and Space Administration and is exercised through the NASA Headquarters, Office of Space Flight Programs. Detailed program management is delegated to the Space Task Group, shown in the center area of Fig. 1. The Space Task Group looks for assistance in research and development activities to all the other NASA Centers and to the three Services, wherever specialized knowledge of facilities exists. For implementation of the ground monitoring network the NASA Langley and Goddard Centers have managed a team composed of a prime contractor, Western Electric, and its subcontractors, with advice and assistance from elements of the Department of Defense, the MIT Lincoln Laboratory, the Federal Aviation Agency, and the Australian Weapons Research Establishment. The operation of this network is handled by NASA through the Department of Defense, drawing on the various national missile ranges, the Australian WRE, and several NASA network stations.

Production of the Mercury spacecraft is done by McDonnell Aircraft Corporation and its subcontractors under a contract with NASA managed by the Space Task Group. The launch vehicles are provided by the Air Force Space Systems Division and its contractors (for the Atlas) and the NASA Marshall Space Flight Center and its contractors (for the Redstone).

Launch and recovery operations are managed by the Space Task Group and are accomplished and supported by the Atlantic Missile Range, McDonnell Aircraft, the Air Force Space Systems Command, Marshall Space Flight Center, a special Navy recovery task force, the Weather Bureau, and a large Department of Defense medical support team drawn from the Army, Navy, and Air Force. For orbital operations, the Public Health Service will supply medical monitors for some of the network stations.

RESEARCH AND DEVELOPMENT

Basic Concept and Methods

The basic concepts for Project Mercury as derived by the studies leading up to the establishment of the Project are illustrated by the set of ground rules shown in Fig. 2.

Methods. The methods by which Project Mercury was planned to be implemented were to use the simplest and most reliable approaches known and to depend, to the greatest extent practicable, on existing technology. To this end, existing ballistic missiles (Atlas and Redstone) were selected as the primary propulsion systems; it was planned to use a drag re-entry vehicle with the entry initiated by retrorockets, with the final descent to be made with parachutes; and to plan on a water landing. Since the Atlas and Redstone were not designed originally for manned flight operation, it was necessary to provide automatic escape systems which would sense impending

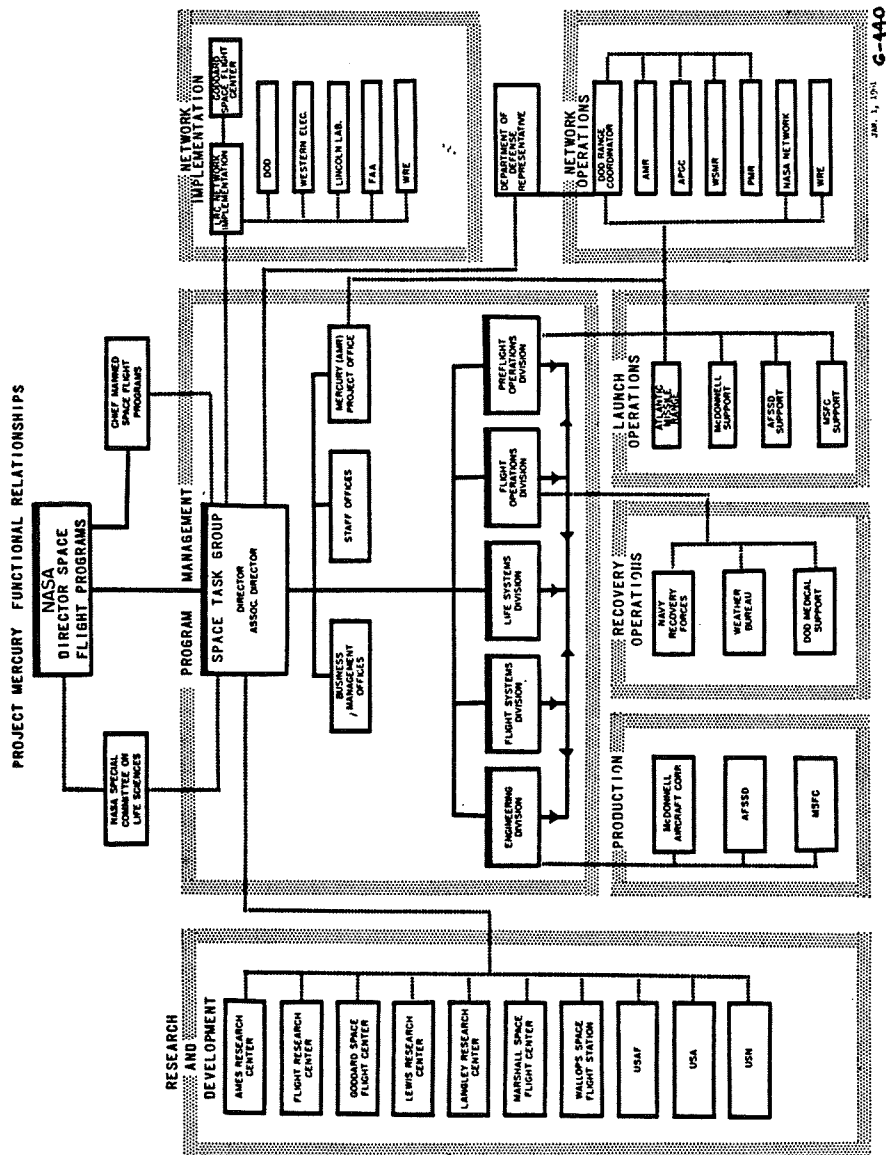


Fig. 1

PROJECT MERCURY

OBJECTIVES

1. ORBITAL FLIGHT AND RECOVERY
2. MAN'S CAPABILITIES IN SPACE ENVIRONMENT

BASIC PRINCIPLES

1. SIMPLEST AND MOST RELIABLE APPROACH
2. MINIMUM OF NEW DEVELOPMENTS
3. PROGRESSIVE BUILD-UP OF TESTS

METHOD

1. DRAG VEHICLE
2. ICBM BOOSTER
3. RETRO ROCKET
4. PARACHUTE DESCENT
5. ESCAPE SYSTEM

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Fig. 2

launch-vehicle malfunctions and separate the spacecraft from the launch vehicle in the event of such malfunctions.

Man had never before flown in space and thus it was felt desirable to include animal flights in the program to provide early biomedical data and to prove out, realistically, the operation of the life-support systems. It was considered wise to monitor the performance of the spacecraft, its systems, and its occupant, whether animal or man, almost continuously. To this end, a world-wide network of tracking, telemetry, and communications stations has been established.

Since a new area of flight was being approached, it was planned to use a build-up type or flight-test program, in which each component or system would be flown to successively more severe conditions in order first to prove the concept, then to qualify the actual design, and finally to prove, through some repeated use, the reliability of the system.

The flight program is being supported by extensive field testing of all components and systems to assure a useful, reliable, vehicle.

General Problems

The problems which demand solution for the successful accomplishment of a project such as Mercury are many and varied, as indicated by the

scope of the organizations involved in the program (Fig. 1). A few of the more basic problems are as follows:

- (1) automatic escape;
- (2) control during insertion;
- (3) behavior of space systems;
- (4) pilots' capability in space;
- (5) in-flight monitoring;
- (6) retrofire and re-entry maneuvers; and
- (7) landing and recovery.

First, the problem of automatic escape from a malfunctioning launch vehicle is vital to pilot safety—the solution chosen, automatic abort-sensing system and escape rocket, has been developed and used in the flight-test program.

The problem of control during insertions into orbit required the development of the real-time computation and display of trajectory and vehicle performance for the Mercury Control Center at Cape Canaveral, together with the Atlas guidance and control system.

The behavior of space systems is being continually studied and proved out by extensive ground tests and by flight tests.

The question of pilots' capability in space can, of course, be studied only through flight tests; however, as discussed in Dr. Voas' paper in this conference, an intensive and extensive astronaut training program is required to prepare the pilots for space flight.

In-flight monitoring has been the subject of considerable training and development effort. Although the complete monitoring network has yet to be put to actual use, various training exercises with the complete network and use of part of the network for the MR-3 and MR-4 flights have been encouraging.

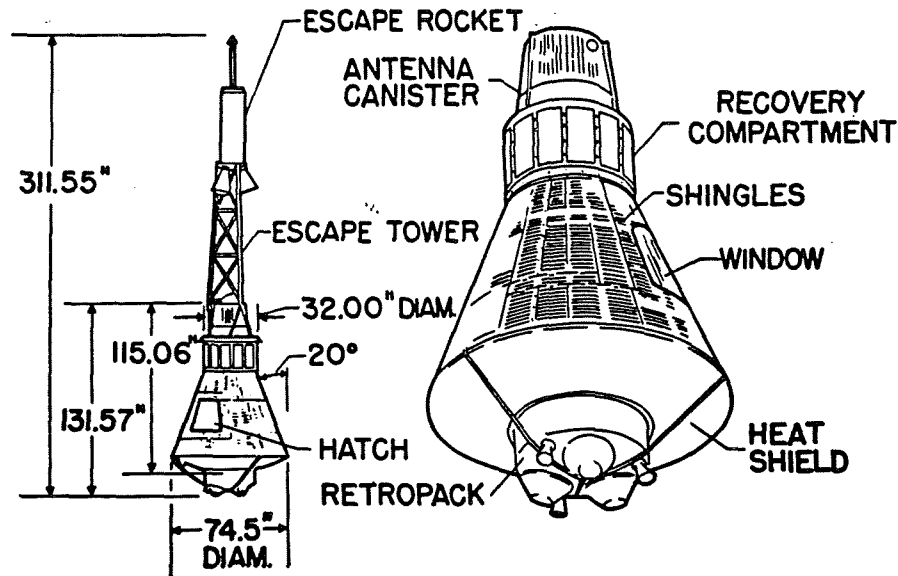
Retrofire and re-entry maneuvers and landing and recovery have been demonstrated in the many flights accomplished in Project Mercury. These problems appear to have been adequately solved; however, these techniques have not been demonstrated for orbital flight.

Spacecraft Description

The spacecraft configuration is shown in Fig. 3.

The over-all length of the vehicle including the escape tower and retropack is just under 26 feet. The maximum diameter of the spacecraft is 74½ inches. The spacecraft configuration is characterized by certain features: the blunt reentry face, the conical afterbody, the cylindrical recovery compartment, and the antenna canister. The blunt end, which is oriented forward during reentry, is protected from reentry heating by a heat shield. For the Redstone missions, a heat shield constructed of beryllium is employed, whereas for the orbital missions an ablative-type shield constructed of fiber glass and resin is used. The inward sloping surfaces of the cone tend to minimize the afterbody heating and the extensions to the cone enhance both the static and dynamic stability. The afterbody is of double-

SPACECRAFT AND ESCAPE-SYSTEM CONFIGURATION



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Fig. 3

wall construction, the walls being separated with bulk insulation material. The outer wall of the conical afterbody and antenna canister consists of overlapping shingles made of thin sheets of refractory metal which dissipate heat by radiation. These shingles are corrugated to provide stiffness. The recovery-compartment outer wall is constructed of a series of beryllium plate elements, which are unrestrained for thermal expansion. The inner-wall structure in the region of the conical portion of the afterbody constitutes the pressure vessel or cabin and is constructed of two layers of thin-gage titanium.

Entrance to the cabin is gained through a hatch in the wall of the conical afterbody. Early capsules had two porthole-type windows incorporated in the side of the spacecraft. These windows utilize heat-resistant glass and are of multipane construction. The later Mercury spacecraft incorporate only a single but much larger window which is located directly above the astronaut's head. This modification was made to give the astronaut a more unrestricted view for making visual observations independent of the existing optical system.

The escape tower is attached to the spacecraft structure by means of a Marman-type clamping band which is held together by explosive bolts. The solid-propellant escape rocket mounted on top of the tower is designed to provide an adequate separation distance in case of launch vehicle failure.

If the launch vehicle fails on the launch pad, the escape rocket will lift the spacecraft to an altitude sufficient to allow deployment of the main parachute. Recent tests of this system simulating an off-the-pad abort, an abort at maximum dynamic pressure, that is, maximum air loading, and an abort at very high altitude have all been successful. In a normal Redstone mission the escape tower is jettisoned by firing the escape motor immediately after the launch-vehicle motor is shut down. A small solid-propellant rocket motor located just behind the escape motor is used to jettison the tower from the spacecraft in an aborted mission.

The retropack, which is shown mounted to the heat shield in Fig. 3, contains six solid-propellant rocket motors, three being retrograde motors and the other three being posigrade motors. The retrograde or braking motors which are used to initiate reentry from orbit will provide a velocity decrement of 450 feet per second along the longitudinal axis of the spacecraft. The posigrade motors, which are smaller and provide a velocity increment of 30 feet per second, are used to effect separation from the launch vehicle. The retropack is attached to the heat shield by means of three metal tie straps. It is jettisoned by firing the single explosive bolt which retains the straps at the center of the retropack.

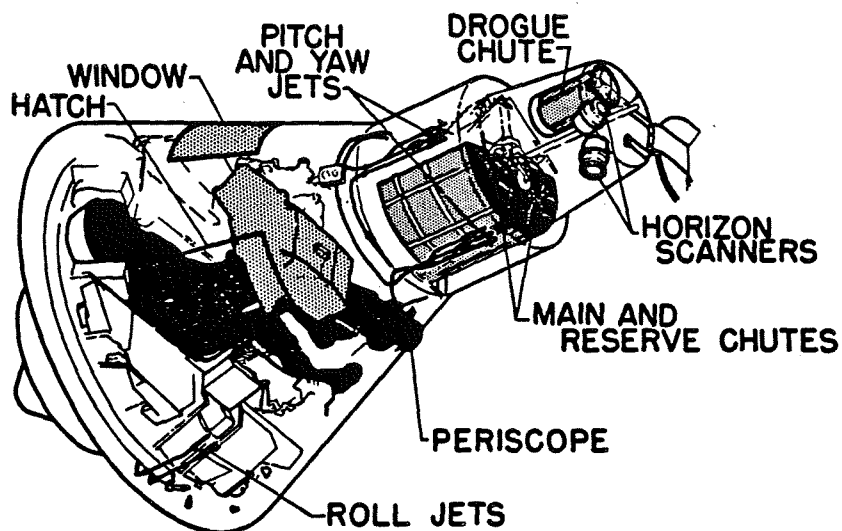
Major Spacecraft Systems

In addition to the heat protection and rocket systems discussed in the foregoing section, the spacecraft incorporates seven other major systems. These systems are: (1) communications, (2) attitude control, (3) environmental control, (4) electrical power, (5) explosive devices, (6) cabin equipment, and (7) landing and recovery systems. Since all the systems cannot be covered in detail in this presentation, only certain features of systems of special interest are discussed. One thing which should be noted at this point is that, although all spacecraft systems have been designed for completely automatic operation, provisions have also been made for operation and control of the systems by the astronaut.

When all the many systems and subsystems are integrated within the spacecraft, the internal arrangement is essentially that shown in the sketch of Fig. 4. With this arrangement, the astronaut has about the same amount of room as in a typical fighter cockpit. The astronaut is shown seated in his contoured couch with his back to the heat shield. It should be noted that the direction of spacecraft travel is reversed between the launch and reentry phases of flight. During launch the small end of the spacecraft is pointed forward but for the reentry the orientation is reversed and the heat shield is pointed forward. This reversal in attitude simplified the astronaut's support system since the support couch is properly aligned for both the acceleration and deceleration phases of flight.

By starting at the small end of the spacecraft one can distinguish such items as the antenna canister, two horizon scanners, the drogue parachute, the main and reserve parachutes, the pitch and yaw jets and associated plumbing, the periscope, the instrument panel, the sidearm controllers, the various electronic packages, and the many other items of equipment needed

SPACECRAFT INTERNAL ARRANGEMENT



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Fig. 4

to carry out the Mercury mission. The environmental control is located primarily below the astronaut's couch.

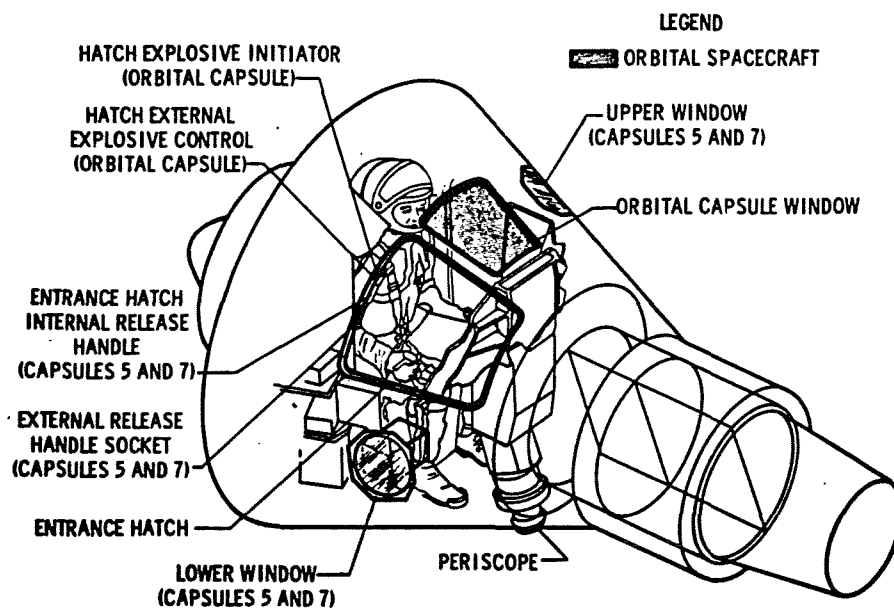
The main components of the landing system are, of course, the parachutes. The drogue parachute, which is housed in the antenna canister (Fig. 4) is a 6-foot ribbon-type parachute which is employed to stabilize and decelerate the spacecraft further prior to main parachute deployment. It is deployed at a nominal altitude of 21,000 feet. The photograph of Figs. 3-4 shows a view of the recovery compartment of the MR-3 spacecraft. The main and reserve parachutes, which are identical, are 63-foot-diameter, ring-sail parachutes. The main parachute is deployed at 10,000 feet through the action of jettisoning the antenna canister. The antenna canister is jettisoned by an electrically fired mortar which is located below the post in the center of the recovery compartment. In the event that the main parachute is damaged or fails to deploy properly, deployment of the reserve parachute is manually initiated by the astronaut.

Spacecraft Modifications

As the program developed and information from research and development tests and from detailed design studies became available, several rather

major detail changes had to be made in the spacecraft. Some of these changes are shown in Fig. 5. The two small portholes for outside vision were replaced by a large trapezoidal window in front of the astronaut. The side entrance hatch was modified by the addition of an explosive opening device to permit egress from the side rather than from the top and rapid egress in an emergency. Unfortunately, this hatch actuated prematurely on the recent flight by Astronaut Grissom and caused an emergency in the recovery area. The problem of inadvertent actuation is now under intensive study and a solution will be found before further manned flights.

CONFIGURATION DIFFERENCES BETWEEN FREEDOM 7 AND LATER SPACECRAFT



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Fig. 5

Other changes in the spacecraft that are not shown in Fig. 5 deal primarily with heat protection. During powered flight, the cross members of the escape tower need extra heat protection—this was accomplished by adding fiber glass plastic covering to the cross members. During entry tests of a full-scale boiler-plate capsule boosted by an Atlas the heating on the afterbody was shown to be higher than first anticipated from small-scale wind-tunnel tests. This result combined with the results of additional tests and analyses caused us to increase the conical afterbody shingles from 0.010-inch thick L-605 cobalt alloy to 0.016-inch thick René 41 nickel alloy and to change the cylindrical afterbody singles to 0.22-inch thick beryllium plates.

Acceleration and Impact Attenuation

One of the primary areas of concern in the design of the Mercury spacecraft was the protection of the astronaut from excessive accelerations during the various flight phases and during landing. Normal boost and re-entry accelerations are an order of magnitude higher than those associated with high performance aircraft; however, they are by no means the highest accelerations to which the astronaut may be subjected. The emergency abort situations actually represent the more severe loading conditions. Under certain conditions the astronaut could be subjected to g -levels of 15 to 17 during the escape maneuvers and of the order of $20g$ during reentry. The astronaut is protected from undue localized loadings by means of the contoured couch mentioned earlier.

IMPACT ATTENUATION

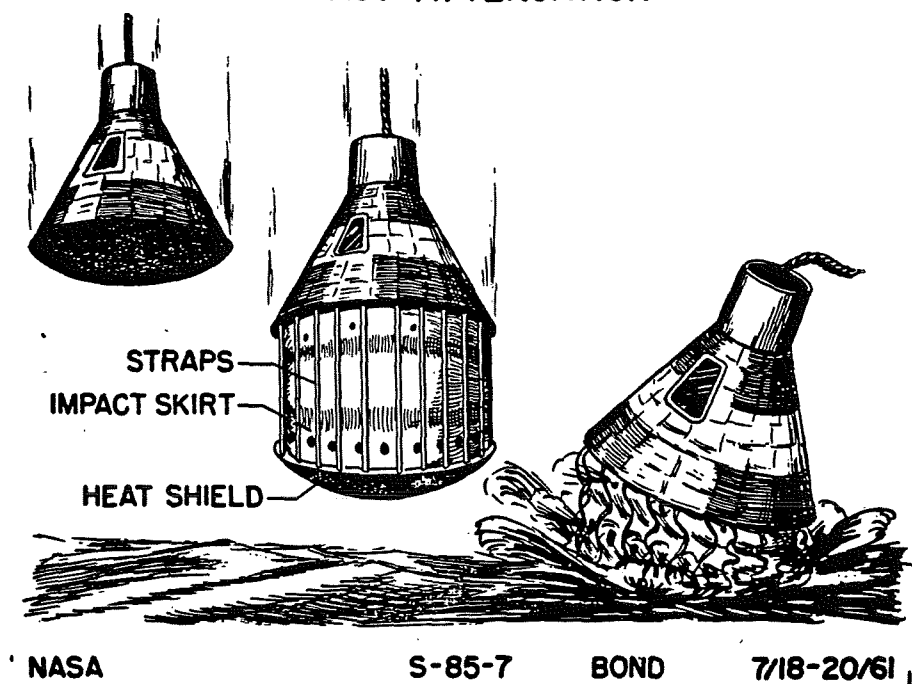


Fig. 6

During the course of testing the spacecraft, it was found that impact on water under certain surface conditions could produce accelerations as high as $40g$ for a few milliseconds with average onset of about $8,000g$ per second to $10,000g$ per second. Impact on land could produce even higher loadings. In order to attenuate these impact accelerations, particularly for cases with attendant high surface winds, a simple air cushion was devised as shown schematically in Fig. 6. The air cushion consists of a 4-foot skirt made of rubberized fiber glass that is attached on the one end to the heat shield

and on the other end to the spacecraft. After the main parachute is deployed, the heat shield is released from the spacecraft structure; thus, the skirt extends and fills with air. Upon impact, the air trapped between the spacecraft and shield is vented through the series of holes in the upper and lower ends of the skirt. A series of thin metal straps which are slightly shorter than the skirt are used to absorb the lateral impact loads and hence prevent damage to the skirt.

A recent series of drop tests with this system with surface winds as high as 20 knots have yielded measured impact accelerations no higher than 16.5g, the average onset rates reduced to 200g per second.

Launch Vehicle Design and Manufacture—The flight-test program of Project Mercury required the use of the three launch vehicles shown in Fig. 7. The Little Joe is a solid-propellant launch vehicle developed by the NASA especially for research and development flight tests of Mercury spacecraft and systems at velocities up to 5,000 feet per second and altitudes

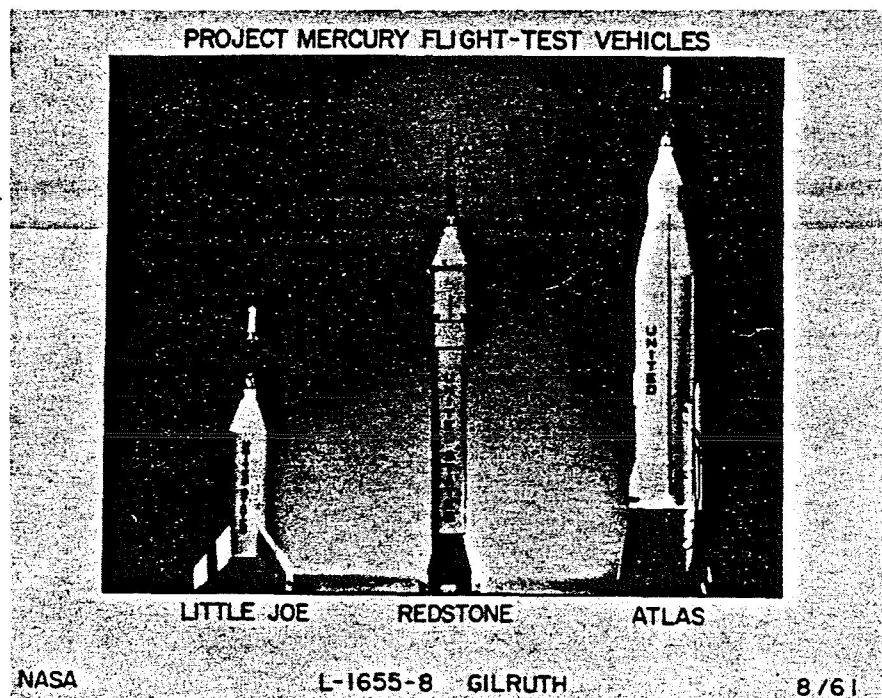


Fig. 7

of up to 80 miles. The Redstone is an adaptation of the Army Ballistic Missile Agency (now NASA George C. Marshall Space Flight Center), and is being used for qualification flight tests of the spacecraft and its systems and for astronaut training in suborbital flights at velocities up to 5,000 miles per hour and altitudes up to 115 miles. The Atlas is an adaptation of the Air Force Atlas missile developed by the Air Force Systems Command. The

Atlas is to be the launch vehicle for the orbital Mercury flights and has been used in research and systems-qualification flight tests.

MOVIE FILMS

During the presentation two movies were shown. The first dealt with the events leading up to the first U.S. manned suborbital flight on May 5, 1961 and included film from an onboard camera focussed on Astronaut Shepard.

The second film dealt exclusively with the research and development program of Project Mercury. It showed scenes of laboratory, wind-tunnel, and flights tests from the following three major R and D periods in the project.

- (a) The basic research in the years prior to 1958.
- (b) The research during 1958 which led to the definition of the Mercury concepts and ground rules, and
- (c) The detailed research and development that guided the design and manufacture of the spacecraft after a contractor was selected.

Concluding Remarks

Project Mercury is now in its most intensive flight test phase. During the last approximately 8 months, we have had on the average of one major firing per month. The program has developed fairly closely along the guidelines and ground rules originally laid out. Although the detailed research and development phase showed the necessity for detailed changes, the basic design concepts have stood the test of time fairly well. Project Mercury is, in itself, a portion of the research and development phase of later more ambitious manned space flight programs.